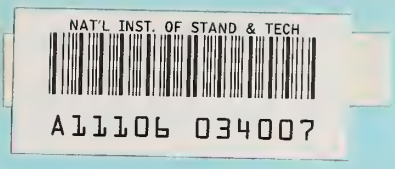
Reference
NBS
PUBLICATIONS



NBSIR 84-2877-2

Center for Electronics and Electrical Engineering

Technical Progress Bulletin

Covering Center Programs, April - June 1984 with 1984 CEEE Events Calendar

July 1984

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INTRODUCTION TO JULY 1984 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the seventh issue of a quarterly abstract journal covering the work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the second quarter of calendar year 1984.

Organization of Bulletin: This issue contains abstracts for all Center papers released for publication by NBS in the quarter and citations and abstracts for Center papers published in the quarter. Entries are arranged by technical topic as identified in the table of contents and alphabetically by first author under each subheading within each topic. Unpublished papers appear under the subheading "Released for Publication". Papers published in the quarter appear under the subheading "Recently Published". Following each abstract is the telephone number of the individual to contact for more information on the topic; unless otherwise noted, this person is the first author. This issue also includes a calendar of Center conferences and workshops for the remainder of calendar year 1984, an announcement of newly released standard reference materials, and a list of sponsors of the work.

Center for Electronics and Electrical Engineering: Center programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards.

The metrological products of these programs aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U. S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

The work of the Center is divided into two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Materials and Processes and Semiconductor Devices and Circuits Divisions in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electrosystems Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information.

Center sponsors: The Center Programs are sponsored by the National Bureau of Standards and a number of other organizations, in both the Federal and private sectors; these are identified on page 21.

Note on Publication Lists: Guides to earlier as well as recent work are the publication lists covering the work of each division. These lists are revised and reissued on an approximately annual basis and are available from the originating division [publications from the Semiconductor Technology Program are covered in a single list, available from either Semiconductor Division].

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SEMICONDUCTOR TECHNOLOGY PROGRAM

Silicon Materials

Released for Publication

Baghdadi, A., **Measurement of the Oxygen and Carbon Content of Silicon Wafers by Fourier Transform Spectrophotometry.**

Fourier transform infrared (FT-IR) spectrophotometry is a rapid, nondestructive characterization technique which is being increasingly applied on a large scale to the routine measurement of the oxygen and carbon content of silicon wafers used for the fabrication of microelectronic devices. Control of the oxygen content is needed to achieve acceptable yields in modern device processing, particularly for those processes which utilize oxide precipitates to protect active regions of devices from contamination by metallic impurities during high-temperature processing. The interlaboratory reproducibility of the measurement is not adequate considering the degree of control of the oxygen that is required. This review focuses primarily on the measurement of oxygen and carbon in silicon and on methods for improving quantitative FT-IR absorption measurements on semiconductor wafers.
[(301) 921-3625]

Recently Published

Lowney, J.R. and Geist, J.C., **Comparison of Models of the Built-In Electric Field in Silicon at High Donor Densities**, J. Applied Physics, 55 (10), pp. 3624-3627 (15 May 1984).

The built-in-electric field for holes due to donor-density gradients in n-type silicon is calculated at 300 K for donor densities between 1×10^{18} and 1×10^{20} cm^{-3}. The calculation is based upon a recent model of band-gap narrowing that includes the effects of ionized impurities, many-body interactions, and an estimate of spatial fluctuations of the band-gap edge caused by the random distribution of donor atoms in the silicon crystal. This model of band-gap narrowing differs significantly from a number of other band-gap narrowing models currently in use in that it agrees with the band-gap narrowing measured optically at 35 and 300 K rather than that inferred from electrical measurements. The built-in-electric field based on this model, which also differs significantly from the results of most previous models, decreases significantly above a donor density of 1×10^{19} cm^{-3} with a reversal of the field above 7×10^{19} cm^{-3}. The implications of this work for photodiodes are discussed.
[(301) 921-3786]

Thurber, W.R., Lowney, J.R., and Phillips, W.E., **Measurement Techniques for High Power Semiconductor Materials and Devices: Annual Report, January 1, 1982 to March 31, 1983,** NBSIR 84-2838 (April 1984).

This annual report is the final one in a series which describes NBS research to develop procedures for the effective utilization of deep-level measurements to detect and characterize defects which reduce lifetime or contribute to leakage current in power-device-grade silicon. During this reporting period, the previously written computer program for predicting excess-carrier lifetime was revised to calculate more accurately lifetimes for high or low injection conditions and in space-charge regions. Comparisons were made between lifetime measurements on platinum-doped silicon diodes and the predictions of the computer model. As part of the effort to extend the procedures to analyze data from nonexponential transient capacitance measurements, the time dependence of the capacitance-voltage relationship of a heavily platinum-doped silicon diode was measured as a function of bias voltage. Included as appendices are three recent publications resulting from the work. A listing of the lifetime-predicting computer program is also an appendix. [(301) 921-3625]

Analysis Techniques

Released for Publication

Seabaugh, A.C., Bell, M.I., Larrabee, R.D., and Oliver, J.D., **High-Frequency Transient-Resistance Spectroscopy of Deep Levels in Semi-Insulated GaAs.**

A new photoinduced transient-resistance technique is used to characterize deep levels in semi-insulating GaAs. In this technique, termed photoresistance deep-level transient spectroscopy (PR-DLTS), an optical pulse is used to generate excess carriers which are trapped by deep levels in the material. The ac resistance of the specimen is monitored, and the resistance transient which occurs after the illumination ends is signal processed in the same way as the capacitance transient in conventional DLTS. Comparison of this technique with the dc current-transient measurement, photoinduced transient spectroscopy (PITS), shows that it is sensitive to the same trapping/detrapping phenomena. PR-DLTS data for the Cr-related deep level is consistent with published DLTS results. Results are reported for materials grown by the horizontal Bridgman method and by the liquid-encapsulated Czochralski technique, both with and without chromium doping. Nineteen specimens from ten different manufacturers are compared.
[(301) 921-3625]

Recently Published

Chang, T-T., **The Calibration Methods and the Reference Materials in ESR Spectroscopy**, Magnetic Resonance Review, 9 (1-3), pp. 65-124 (May 1984).

This paper reviews the calibration methods and reference materials that have been recommended or have been in use in ESR [electron spin resonance] spectroscopy. Methods for the measurement of microwave frequencies and magnetic fields are briefly mentioned. Methods to measure the Q-factor of a microwave cavity are described. The calculation and measurement of the microwave magnetic field in an ESR resonance cavity are described in detail. Methods for the determination of the concentration of the paramagnetic centers in a sample are described after a discussion of the theoretical background. Precautions and factors that affect the accuracy of this determination are discussed. Reference materials, in 16 groups, are listed. Recipes for preparation of some of these standard samples are also given.
[Contact: Larrabee, (301) 921-3786]

Insulators and Interfaces

Released for Publication

Candela, G.A. and Chandler-Horowitz, D., **An Ellipsometry System for High Accuracy Metrology of Thin Films**, to be published in Proc. SPIE - The International Society for Optical Engineering [paper given at conference, May 1-4, 1984, Arlington, VA].

A computer-controlled spectroscopic ellipsometer of high accuracy has been designed and constructed. A theta-two-theta goniometer unit and optical rail system allows various ellipsometric methods to be used to measure the parameters Δ and Ψ. Three important methods under study for accuracy, precision, and speed of measurement are the conventional null method, the rotating analyzer method, and the principal angle method. All the goniometer angles, including the angle of incidence, can be measured to an accuracy of 0.001 deg. The present light sources are two lasers with fixed wavelengths, 632.8 nm and 441.6 nm, in addition to a monochromator that can be used to scan the wavelength range from 190 to 2600 nm. A unique sample alignment system which utilizes two quadrant detectors has been developed and a simple but very effective nulling scheme is used. This instrument is primarily used for the metrology of semiconductor materials and for the calibration of reference

Insulators and Interfaces, cont'd.

standards for thin film thickness and refractive index. [(301) 921-3625]

Dimensional Metrology

Recently Published

Nyyssonen, D., **National Bureau of Standards, A Review of NBS's Activities in the Area of Linewidth Measurement**, Proc. Scientific Apparatus Makers Association Conf., The Future of Optical Technologies in the Semiconductor Industry, pp. 1-7 (March 1984) [Conference, Sunnyvale, CA May 23, 1983].

This manuscript is a summary of a talk covering current NBS activities in linewidth measurement including research, calibration of standard reference materials (SRMs), development of calibration procedures and test methods, and technology transfer. The current status of photomask linewidth SRMs is discussed (anti-reflective "gold" chromium SRMs 474 and 475, bright chromium SRM 476, and the 3X reticle SRM 1830). Wafer linewidth measurements are divided into two categories, thin layers (less than approximately 200 nm) and thick layers. The design of the linewidth standard for thin layers is described. Research problems remaining for thick layers are described along with current NBS waveguide modeling. Instrumentation used for both photomask and wafer calibrations is also described. NBS plans for development of SEM/e-beam instrumentation and SRMs are also included.
[(301) 921-3786]

Integrated Circuit Test Structures

Released for Publication

Carver, G.P. and Wachnik, R.A., **TERRY-2: A Test Chip for Characterization of the Performance of Buried-Channel Charge-Coupled Device (CCD) Imagers**, to be published as NBSIR 84-2894.

Test chip TERRY-2 is intended to be used for characterization of the performance of buried-channel charge-coupled device (CCD) imagers fabricated with a double-polysilicon-gate process which includes several implants. Test structures in TERRY-2 address two areas judged to be key ones for CCD performance: device parameters and process parameters, including material properties. TERRY-2 is a modular chip designed for automatic testing; selected devices can be wire bonded for testing various environmental effects; a region containing test structures can be thinned in the same manner as a back-side-illuminated CCD would be; and large devices can be beveled for spreading resistance or physical analysis. This report describes the features of TERRY-2, the test structure designs, and the measurement procedures. The technique of charge pumping for measuring interface state density is discussed in an appendix.
[(301) 921-3786]

Yen, D., Glendinning, W.B., and Linholm, L.W., **An Electrical Test Structure for Proximity Effects Measurement and Correction.**

This paper describes the design of a proximity effect test structure and electrical test method for estimating the magnitude of proximity effects in electron-beam lithography. The test structure consists of a van der Pauw cross resistor for measuring sheet resistance, a bridge resistor for measuring electrical linewidth, and a second bridge resistor simulating a close line-space environment for measuring electrical linewidth where proximity exposure effects from nearby patterns may be encountered. In this experiment, test structures were delineated in aluminum on silicon wafers using electron-beam exposure and wet chemical etching. Electrical measurements from these test structures are compared to optical measurements to verify the measurement method. In addition, results from the test structures are used to estimate the Gaussian parameters for the Gaussian

Integrated Circuit Test Struc., cont'd.

model commonly used for proximity corrections.
[(301) 921-3621]

Recently Published

Roenker, K.P. and Linholm, L.W., **An NMOS Test Chip for a Course in Semiconductor Parameter Measurements**, NBSIR 84-2822 (April 1984).

This report describes an NMOS test chip, NBS-40, which was developed to be used in graduate level electronics engineering courses involving semiconductor parameter measurements associated with the fabrication of integrated circuits. The 35 test structures included in the test chip and their use in materials, device, and process parameter measurements are described. Details of the silicon gate NMOS process used in the chip fabrication are also provided.
[Contact: Linholm, (301) 921-3541]

Process and Device Modeling

Released for Publication

Albers, J., **An Alternative Approach to the Calculation of Four-Probe Resistances on Nonuniform Surfaces.**

An alternative approach to the calculation of four-probe resistances of nonuniform resistivity structures is presented. The basis of this approach is the form of the spreading resistance correction factor integral as given by Berkowitz and Lux. When this form is used, the difference of the spreading resistances involved in the four-probe resistance may be written as a simple integral which does not contain Bessel functions. Also, the derivative of the spreading resistance which is involved in the probe-spacing experiment simulation yields a simple algebraic expression. The resulting equations for the four-probe resistance and the derivative function are formally shown to be independent of both the probe radius and the probe-current density and involve only the kernel of the spreading resistance correction factor integral (sometimes known as the integrating factor). For the case of a uniform layer over insulating, conducting, or no boundaries (a semi-infinite slab), analytic expressions are derived for the four-probe resistance and the derivative function and are investigated as a function of the probe spacing. For nonuniform resistivity structures, a relatively simple numerical procedure is used for the evaluation of the four-probe resistance integral. The results obtained from this numerical technique for the four-probe resistance and the algebraic expression for the derivative function are compared with those obtained from more extensive numerical techniques and are shown to be in excellent agreement. The evaluation of the four-probe resistance and the derivative function by means of the variational technique described by Choo and coworkers is presented. A caveat concerning the use of the Gauss-Laguerre technique for calculating the four-probe resistance is also discussed.
[(301) 921-3621]

Berkowitz, H.L. and Albers, J., **Simplified Method for Calculating Four-Probe Resistances on Nonuniform Structures.**

A simple method for calculating the four-probe resistance as an integral involving only the kernel of the correction factor integral (and independent of the probe radius and the probe-current density) is presented. Analytic expressions are derived for uniform layers and are investigated as a function of the probe spacing. For nonuniform resistivity structures, a simple numerical procedure is presented for the evaluation of the four-probe resistance and is compared with more extensive techniques.
[Contact: Albers, (301) 921-3621]

Wilson, C.L., Roitman, P., Marchiando, J.F., and Blue, J.L., **Modeling of the**

Process & Device Modeling, cont'd.

Process Sensitivity of Submicron Silicon MOSFETs.

When short-channel MOSFET transistor models are compared to experimental data, the uncertainty in the process models used as inputs often requires that some of the process model parameters be adjusted to fit the data. In this work the process sensitivity of the source-drain junction is modeled. We find that sensitivity of the saturated drain current to the source-drain junction depth increases sharply at some critical value of the junction depth. This value of junction depth is reached when the junction depth is equal to the zero biased depletion region width. As the contribution of the source drain junction to the sum of the depletion width and the junction depth becomes significant, the total change in channel field caused by the source-drain junction is a maximum.
[(301) 921-3541]

Recently Published

Albers, J., **Semiconductor Measurement Technology: TXYZ: A Program for Semiconductor IC Thermal Analysis,** NBS Special Publication 400-76 (April 1984).

A computer program, TXYZ, for the thermal analysis of semiconductor integrated circuits is presented and its applications are discussed. The program makes use of the closed form, analytic solution of the steady-state heat flow problem for a rectangular three-layer structure with multiple heat sources on the top layer. The temperature may be obtained for any point or set of points in the structure and is useful in the determination of the steady-state thermal response of IC chips and packages.
[(301) 921-3621]

Bennett, H.S. and Wilson, C.L., **Analysis of the Statistical Comparisons of Data on Band-gap Narrowing in Heavily Doped Silicon: Electrical and Optical Measurements,** J. Applied Physics, 55, 3582-3587 (May 15, 1984).

A system of subroutines for iteratively reweighted least squares (IRLS) computations has been applied to the published measured and theoretical data on band-gap narrowing in heavily doped silicon. The data include electrical and optical measurements at room temperature, photoluminescence and optical measurements for temperatures below 35 K, and theoretical calculations at 300 K and 0 K. This procedure, IRLS, allows an unambiguous comparison of the various experimental and theoretical data in band-gap narrowing to be made. The results are (1) that the optical absorption data and theory are consistent at both 300 K and at temperatures below 35 K; (2) that the electrical and optical measurements are not consistent; and (3) that when compared with the low temperature optical absorption data, the photoluminescence data have low statistical significance. [(301) 921-3541]

Blue, J.L. and Wilson, C.L., **Numerical Methods for Solving Coupled Semiconductor Equations on a Minicomputer,** Proc. Elliptic Problem Solvers II, Academic Press, pp. 521-530 (April 1984).

A general mathematical model for analyzing currents and fields in semiconductor devices requires three coupled nonlinear elliptic partial differential equations in two dimensions. A general-purpose solver for systems of coupled nonlinear elliptic partial differential equations is used. The numerical framework is linear elements on triangles, with nonuniform triangulations. The nonlinear finite element equations are solved by approximate Newton methods; the linearized equations are solved by sparse Gaussian elimination and by multi-level iteration. For accurate solutions, triangle refinements are generated adaptively.
[Contact: Wilson, (301) 921-3541]

Process & Device Modeling, cont'd.

Roitman, P., Albers, J., and Myers, D.R., **An Investigation of the Two-Dimensional Shape of Ion-Implanted Regions**, J. Applied Physics, 55 (12), pp. 4436-4443 (June 15, 1984).

The two-dimensional shape of arsenic ion-implanted regions in single-crystal silicon was investigated both experimentally and theoretically. Experimentally, two techniques were shown to have the necessary submicron resolution: a junction etch process and an SEM-induced current collection method. A comparison of junction depths determined by the etch technique and the EBIC techniques with the depths calculated using several amorphous target codes was made. For the case of low temperature (600°C) anneals, the etch technique agrees very well with the junction depths predicted by the amorphous target code due to Winterbon. The lateral junction locations obtained from the etch technique are in good agreement with the predictions of a two-dimensional Monte Carlo code (TRIM) which indicates that the arsenic does not show any significant lateral scattering under mask edges. For the high temperature (1000°C) anneals, the etch and EBIC techniques agree with each other. Comparison with arsenic-diffusion models shows that concentration-dependent effects are important.
[(301) 921-3621]

Radiation Effects

Released for Publication

Galloway, K. F., Gaitan, M., and Russell, T.J., **A Simple Model for Separating Interface and Oxide Charge Effects in MOS Device Characteristics.**

A simple model to describe radiation effects on MOSFET electrical characteristics is presented. The key assumption is that mobility degradation in an enhancement mode MOSFET is predominantly due to charged interface traps. Model predictions are compared with measured values of interface trap density and device I-V curves.
[(301) 921-3541]

Packaging

Released for Publication

Moore, B.A. and Ruthberg, S., editors, **RADC/NBS Workshop, Moisture Measurement and Control for Semiconductor Devices, III**, to be published as NBSIR 84-2852.

The workshop, one of a series concerned with measurement problems in integrated circuit processing and assembly, served as a forum to examine the continuing progress that has been made in the measurement and control of moisture in hermetically packaged semiconductor devices. Thirty-four presentations are included which contain detailed information for securing hermetic packages with low moisture content. Agreement in measurement has been obtained with the mass spectrometer for cerdip and metal packages at the 5000 ppmv level of moisture through the use of suitable moisture generators, a 3-volume calibrator, calibrated dewpoint hygrometers, and appropriate operational procedures. An approach is given for a reproducible and reliable transfer package. However, the increased use of organic materials in new and rapidly expanding technologies such as VLSI/VHSIC and hybrid packaging presents new and more complex challenges to accurate measurement of interior moisture.
[Contact: Ruthberg, (301) 921-3625]

Recently Published

Harman, G.G., **The Microelectronic Ball-Bond Shear Test - A Critical Review and Comprehensive Guide to Its Use**, Solid State Technology, 27 (5), pp. 186-197 (May 1984).

The microelectronic ball-bond shear test

Packaging, cont'd.

was first developed in 1967. Since then, it has been used to study the effects of contamination on bondability, to characterize the reliability of gold-aluminum intermetallic formation, to control bonding machine parameters for device production, and to troubleshoot such production problems as poor metallization adherence and contamination.

This paper critically reviews all of these uses and identifies ways that the shear test can be implemented to improve bond yield and assure long term bond reliability. A manual shear probe is described that can be quickly made from the blade of a jeweler's screwdriver. This probe was instrumented with a strain gage and the shear test results compared within 10% of those obtained from a machine. The paper also presents data obtained from shearing both aluminum-ball and -wedge bonds and determines how the shear testing machine requirements for these differ from those required to test gold ball bonds.

The shear strengths of both annealed gold and aluminum were measured and compiled in a plot of shear force versus diameter of the bonded area in order to determine the maximum force obtainable when shearing both gold and aluminum bonds having differing ball size. Interferences that may produce erroneous shear test results, such as friction rewelding of gold balls on gold metallization, are described along with ways of avoiding such problems. Finally, the implications of pending ASTM and military standards on the widespread use of the shear test is discussed. This paper is intended to present all information necessary to both understand and implement the shear test for research purposes or for production control.
[(301) 921-3621]

Other Semiconductor Metrology

Recently Published

Dodge, M.J., **Refractive Properties of Magnesium Fluoride,** Applied Optics, 23 (12), 1980-1985 (June 15, 1984).

The refractive indexes of a commercially available specimen of single-crystal MgF_2 were determined for both the ordinary and extraordinary rays at selected wavelengths from 0.2026 to 7.04 μm. Measurements were made by means of the minimum-deviation method on a precision spectrometer near 19°C. The experimentally determined index values for each polarization were fitted to a three-term Sellmeier-type dispersion equation of the form:

$$n^2 - 1 = \sum A_j\lambda^2/(\lambda^2 - \lambda_j^2),$$

relating the refractive index n to the wavelength of interest λ, the wavelength Aj. The birefringence was computed as a function of wavelength from the calculated index values obtained for the two polarizations. The dispersion coefficients were also determined for the O-ray and for the birefringence. The results of this study are compared with previously reported work on the refractive properties of MgF_2.
[(301) 921-3625].

Kowalski, P., Lankford, W.F., and Schafft, H.A., **Nondestructive Measurement of Solar Cell Sheet Resistance Using a Laser Scanner,** IEEE Trans. Electron Devices, ED-31, pp. 566-570 (May 1984).

Experimental data have shown that a laser scanner can be used as a probe to make nondestructive measurements of solar cell sheet resistance with an accuracy of several percent. The photovoltaic response from cells with controlled sheet resistance was measured using the scanner and compared with the theoretical predictions made by other workers. Several limitations in this technique are identified and a measurement methodology is suggested.
[Contact: Schafft, (301) 921-3621]

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

Released for Publication

Lawton, R.A., **An Efficient Antialiasing Filter,** to be published in Proc. Conference on Precision Electromagnetic Measurements [paper to be given at Conference, Delft, Netherlands, August 20-24, 1984].

The application of a solid state reference filter as an efficient antialiasing filter is described. The analytical basis for the efficiency of this filter is described, and a specific example of measuring a 1024-point waveform with an RC filter and the solid state filter is given. [(303) 497-3339]

Cryoelectronic Metrology

Released for Publication

Kautz, R.L. and Monaco, R., **Survey of Chaos in the rf-Biased Josephson Junction.**

Chaotic behavior in the rf-biased Josephson junction is studied through digital simulations of the Stewart-McCumber model. Chaotic states are characterized by Poincare sections, Liapunov exponents, and power spectra. Models are presented which explain some features of the chaotic spectra. The parameter range over which chaotic behavior occurs is determined empirically for a broad range of dc bias, rf bias, and the hysteresis parameter for a fixed rf frequency. It is shown that chaos does not occur if either the dc bias or the rf bias is very large. An attempt is made to explain the boundaries of the chaotic region in terms of simple models for chaotic behavior. [(303) 497-3391]

Antenna Metrology

Released for Publication

Stubenrauch, C.F. and Francis, M.H., **Comparison of Measured and Calculated Mutual Coupling in the Near Field between Microwave Antennas,** to be published as NBSIR 84-3010.

Measurements of near-field mutual coupling were performed between two moderate sized microwave antennas and compared to coupling calculated using recently developed computer programs. Input data for the programs are the complex far-field radiation patterns of the antennas. Experimentally determined and calculated coupling as a function of both transverse displacement and separation agree closely except for a constant offset observed in some cases. In addition, coupling values computed using a program which approximates the far-field radiation patterns were compared to experiment and found to be satisfactory. [(303) 497-3927]

Wyss, J.C. and Sheeran, S., **A Passive, Optical Modulator and Link for Antennas.**

This paper describes a technique for coupling an antenna to a receiver using a passive, fiber optical link. This technique should avoid pickup and electromagnetic perturbations normally associated with the use of electrically conductive cables. Laser light (632.8 nm) is modulated at the antenna by an electro-optic, lithium tantalate crystal and is then transmitted with a fiber optic cable to the receiver electronics. Using an avalanche photodiode, the amplitude-modulated optical signal is converted to an electrical signal. The crystal is mounted directly on an antenna without amplifiers or other active electrical components. Using a broadband antenna with fields generated in an anechoic chamber and a standard TEM cell, the frequency response was measured to drop 3 dB per 1.0 GHz from 100 MHz to at least 2.0 GHz, with a signal-to-noise ratio of 5 dB with a 1.0-V/m field and a 1.0-kHz bandwidth. A dynamic range of at least 60 dB is shown. [Contact: Nahman, (303) 497-5167]

Antenna Metrology, cont'd.

Recently Published

Fitzgerrell, R.G., **A Source of E and H Fields for Antenna-Factor Calibration**, IEEE Trans. Electromagnetic Compatibility, EMC-26, No. 2, pp. 58-65 (May 1984).

The loop cell used for calibration is fabricated using two intersecting metal sheets joined at the intersection and forming a 36° angle. A section of a loop is mounted between two coaxial panel jacks, one on each sheet located at a distance equal to the loop radius from the intersection. A known current through this section of electrically small loop produces calculable E and H fields between the sheets in the plane of the loop. These known fields may be used to determine the antenna factor of small E and H antennas placed in the field if the mutual impedance due to the antenna images in the sheets is negligible and the antenna is not close to the open edges of the cell. Measured and calculated antenna factors agree within ± 2 dB between 0.25 and 1000 MHz.
[(303) 497-3737]

Noise Metrology

Released for Publication

Miller, C.K.S. and Daywitt, W.C., **The NBS Switching Radiometers**, to be published as NBSIR 84-3004.

An error analysis for the Dicke radiometers used by the National Bureau of Standards (NBS) in WR90 waveguide noise calibration services for sources with noise temperatures above 1000 kelvin is discussed.

A list of measurement frequencies currently available in the WR90 and WR62 bands is presented.
[(303) 497-3131]

Miller, C.K.S. and Daywitt, W.C., **The NBS WR62 and WR90 Reference Noise Standards**, to be published as NBSIR 84-3005.

The basis for the National Bureau of Standards (NBS) WR90 and WR62 Waveguide Reference Noise Standards and the corresponding error analyses are described. The standards are heated (1270K) thermal noise generators, and a derivation of their output noise temperature equations is also presented. Results of comparisons of the NBS WR90 standard with those of Sweden, England, Australia, and Japan are included.

The text is extracted from course notes presented at NBS in 1970, and hence does not include descriptions of standards constructed at NBS since that time.
[(303) 497-3131]

Microwave and Millimeter-Wave Metrology

Released for Publication

Juroshek, J.R. and Hoer, C.A., **A Technique for Extending the Dynamic Range of the Dual Six-Port Network Analyzer.**

The dynamic range of the six-port type of automatic network analyzer is typically limited to measuring two-port devices with a transmission coefficient S_{12} in the range of 0 to -60 dB. This paper describes a subcarrier approach for extending the dynamic range of the dual six-port network analyzer. The subcarrier is generated by inserting a 10-kHz, biphase modulator ahead of one of the six-ports. The 10-kHz signal is detected with a coherent vector voltmeter. With the subcarrier approach, measurements of S_{12} in the range of -60 to -100 dB can be made.

Test results are presented showing measurements of S_{12} = -80 dB with a precision of ±0.05 dB or better, and an accuracy of ±0.16 dB or better at 3GHz. Measurement results are also presented showing the dynamic range achievable with thermistor and barretter detectors.
[(303) 497-5362 or -3196]

Microwave & Millimeter-Wave, cont'd.

Recently Published

Juroshek, J.R. and Hoer, C.A., **A Dual Six-Port Network Analyzer Using Diode Detectors,** IEEE Trans. Microwave Theory and Techniques, MTT-32, No. 1, pp. 78-82 (January 1984).

The performance of a dual six-port network analyzer using diode detectors is described. The network analyzer operates over the 2-18 GHz band using commercially available, low-barrier, Schottky diodes. The paper describes the process for calibrating the diodes for deviation from square-law. Measurement results are presented showing the accuracy and precision of the six-port network analyzer when measuring 1-port and 2-port devices.
[(303) 497-5362 or -3196]

Laser Metrology

Released for Publication

Simpson, P.A., Johnson, E.G., Jr., and Etzel, S.M., **A Calorimeter for Measuring High-Energy Optical Pulses.**

Two similar calorimeters for measuring laser pulses in the range 1 kJ to 15 kJ are described. The calorimeters, which are electrically calibrated, can be operated anywhere from the ultraviolet to the infrared by selecting the proper materials for the volume absorber and deflecting mirror. Operation of each calorimeter is controlled by a dedicated desk-top computer. The theoretical basis for the calorimeters is given as are the constructional and operational details. The computer programs that are used are included in the appendices.
[(303) 497-3789]

Optical Fiber Metrology

Released for Publication

Franzen, D.L., **Determining the Effective Cut-off Wavelength of Single-Mode Fiber: An Interlaboratory Comparison.**

The National Bureau of Standards (NBS), in cooperation with the Electronic Industries Association, conducted an interlaboratory measurement comparison among six fiber manufacturers to determine the effective cut-off wavelength of single-mode fiber. Measurement techniques based on transmitted power were used to determine cut-off wavelength on four fibers designed for single-mode operation at 1300 nm. NBS also contributed results using a spectral near-field technique.

The range of measurements covered by an interval of one standard deviation for the various techniques extends from 6 to 12 nm. With the appropriate data analysis, single bend attenuation and power step methods give the same results. Both techniques are easily implemented as extensions to the usual spectral attenuation measurement.
[(303) 497-3346]

Other Fast Signal Topics

Released for Publication

Hill, D.A., **Radio Propagation in a Coal Seam and the Inverse Problem.**

The longwall method of coal mining in underground coal seams is very efficient in uniform seams, but coal seam anomalies can make the method unprofitable and unsafe. This paper describes the theoretical basis for detection of coal seam anomalies using medium frequency (MF) radio transmission over paths on the order of 200 meters in length.

The key to the method is the sensitivity of the attenuation rate of the coal seam mode of propagation to changes in the coal seam parameters, such as height or electrical conductivity. From a large number of transmission paths, the principles of tomography can be used to reconstruct an image of the seam.
[(303) 497-3472]

Other Fast Signal Metrology, cont'd.

Metrology for Electromagnetic Technology: A Bibliography of NBS Publications, Edited by Kamper, R.A. and Kline, K.E., to be published as NBSIR 84-3014.

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NBS in the period from January 1970 through December 1983. A few earlier references that are directly related to the present work of the Division are included.
[(303) 497-3535]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Fulcomer, P.M., **Calibration Check of Bonneville Power Administration 60-Hz Electric Field Exposure Monitor & Measurement of Its Surface Field Enhancement for Various Uniform & Nonuniform Operating Configurations**, to be published as NBSIR 84-2885.

This report presents the results of tests requested by the Bonneville Power Administration (BPA) on a 60-Hz Electric Field Exposure Monitor (EFEM) developed by their Instrumentation and Standards Branch. The unit is designed to be worn on the body, such as in a shirt pocket or attached to the clothing. The calibration of two sample units is examined, information on surface field enhancement (which results from the EFEM sensors' elevated position relative to the surface of the body) is presented, the effect of material covering the sensor is specified, and the applicability of calibration and operational information obtained in uniform fields to nonuniform fields is investigated.
[(301) 921-3121]

Hebner, R.E., **Development of Power System Measurements -- Quarterly Report January 1, 1984 to March 31, 1984**, to be published as NBSIR 84-2898.

This report documents the progress on three technical investigations sponsored by the Department of Energy and performed by the Electrosystems Division, the National Bureau of Standards. The work described covers the period from January 1, 1984 to March 31, 1984. The report emphasizes the performance of ion counters like those used to measure the ions near dc transmission lines, the production rates of oxyfluorides in SF_6 corona discharges, and in the measurement of space charge associated with a pressboard interface in transformer oil.
[(301) 921-3121]

Hebner, R.E., Kelley, E.F., Forster, E.O., and FitzPatrick, G.J., **Observation of Prebreakdown and Breakdown Phenomena in Liquid Hydrocarbons II Nonuniform Field Conditions**, to be published in the Conference Record of the Eighth IEEE International Conference on Conduction and Breakdown in Dielectric Liquids [paper to be given at Conference, Pavia, Italy, July 24-27, 1984].

The prebreakdown processes have been recorded in n-hexane, toluene, and Marcol 70, both in a pure state and with selected impurities. The study was carried out using a point-plane geometry. A low ionization potential additive had only a small effect on the breakdown voltage or the streamer propagation speed but did significantly alter the shape of the prebreakdown streamer when the needle was the anode. For a cathode needle, chemical impurities affected the breakdown voltage.
[(301) 921-3121]

Laug, O.B., **A Wideband Transconductance Amplifier for Current Calibrations.**

A wideband transconductance amplifier for current calibrations is described.

Power Systems Metrology, cont'd.

The amplifier will deliver a ground-referenced constant current of 5 A rms from dc to over 100 kHz. Its stable magnitude and phase permit it to be used in precise power calibration systems to provide the current component of a phantom power source.

The amplifier also provides a ground-referenced voltage output of 1 volt per ampere for monitoring the magnitude and phase of the output current.
[(301) 921-2727]

McKnight, R.H., **The Measurement of Net Space Charge Density Using Air Filtration Methods**, to be published in IEEE Trans. Power Apparatus and Systems [paper to be given at Conference, Seattle, WA, July 15-20, 1984].

The efficiency of a high efficiency particulate air (HEPA) or absolute filter for removing charge from an air stream has been measured for a variety of space charge and air flow conditions. Ion densities ranged from 10^5 to $10^6/cm^3$ and were for positive and negative space charge as well as mixtures. The space charge was made up predominantly of ions with mobilities greater than 0.1×10^{-4} $m^2/V \cdot s$. For all conditions studied, the transmission of the filter was less than 0.1%. For space charge consisting of ions of one polarity, space charge density measurements made using HEPA filters and ion counters may be compared directly. The filter is well suited for accurate measurements of net space charge density.
[(301) 921-3121]

Recently Published

Hebner, R.E., **Development of Power System Measurements -- Quarterly Report October 1, 1983 to December 31, 1983**, NBSIR 84-2861 (DoE) (May 1984).

This report documents the progress of three technical investigations sponsored by the Department of Energy and performed by or under a grant from the Electrosystems Division, the National Bureau of Standards. The work described covers the period October 1, 1983 to December 31, 1983. This report emphasizes the errors associated with measurements of electric and magnetic fields, the properties of corona in compressed SF_6 gas, and the measurement of interfacial phenomena in transformer oil.
[(301) 921-3121]

Hillhouse, D.L., Petersons, O., and Sze, W.C., **A Simplified System for Calibration of Coupling Capacitor Voltage Transformers**, IEEE Trans. Power Apparatus and Systems, PAS-103, No. 5, pp. 1092-1098 (May 1984).

Metering accuracy coupling capacitor voltage transformers (CCVTs) are installed permanently in 230-500 kV substations and must be calibrated in place. Several years ago, the National Bureau of Standards (NBS) developed a field calibration system, with uncertainties of ±0.1% and ±0.3 milliradian.

This paper describes a simpler system, consisting of a 15 kV standard transformer and its power supply, a capacitive transfer standard divider, and a voltage comparator. In field tests, this system agreed with the prototype to within ±0.03% and ±0.1 milliradian. The new system can be transported in a non-dedicated truck, and operated from the substation control house or a van.
[(301) 921-3121]

Kelley, E.F. and Hebner, R.E., **Electro-Optic Electric-Field Measurements Near Oil-Pressboard Interfaces**, Conference Record 1984 IEEE International Symposium on Electrical Insulation, Montreal, Canada, pp. 311-314 (June 11-13, 1984).

Electro-optical Kerr-effect measurements are made to characterize the electric field in the vicinity of pressboard interfaces in transformer oil. The interfaces are placed between parallel

Power Systems Metrology, cont'd.

plate electrodes and are oriented parallel to the field direction and in contact with both electrodes. The electric field enhancement in the liquid alone (due to space charge) is compared with the enhancement with interfaces installed. These results serve to better define the roles of space charge and interfacial surface charging in pressboard/transformer-oil high-voltage systems.
[(301) 921-3121]

Kelley, E.F., Hebner, R.E., FitzPatrick, G.J., and Forster, E.O., **The Effect of Aromatic Impurities on the Positive Streamer Growth in Marcol 70**, Conference Record 1984 IEEE International Symposium on Electrical Insulation, Montreal, Canada, pp. 284-287 (June 11-13, 1984).

The growth of positive streamers has been photographed in Marcol 70 in the presence and the absence of dimethylaniline (DMA). Marcol 70 is a fluid which is chemically similar to transformer oil but with the aromatic components removed. This combination has been studied previously by other authors, and was chosen for this work, because it should provide useful information on the contribution of aromatic components to the electrical properties of transformer oil. As in earlier studies, it was noted that the positive streamers initially propagate at or near sonic speed. After the streamer has propagated some distance across the inter-electrode gap, a supersonic secondary streamer develops that leads to breakdown. The initiation of this second event is significantly delayed by DMA. As in earlier studies in n-hexane, the reason for this behavior is assumed to be structural changes in the streamers because of the low ionization potential of DMA. These structural changes, in turn, lead to a modification of the electric field distribution between the positive streamer tips and the plane cathode. Information derived from the photographs suggests that the field distribution changes from a very nonuniform to a more uniform one, which would lead to the observed higher breakdown voltages. The data presented are not in complete agreement with those reported in the literature. This disagreement is believed to be attributable to experimental differences.
[(301) 921-3121]

Ramboz, J.D. and Flach, D.R., **High-Current Measurement Techniques**, NBSIR 84-2881 (May 1984).

The measurement of very high ac currents presents special problems in the selection of current sensors, instrumentation, and techniques. This report discusses initial test results for Rogowski coils and high-capacity current shunts often used to measure large ac currents. Eight Rogowski coils of three sizes and ratings were tested at a nominal current of 1000 A. The coils were compared against an NBS precision air-core mutual inductor to obtain a measure of complex sensitivity, positional sensitivity, gap-separation sensitivity (for the split-coil types), and proximity effects of the return conductor and of ferromagnetic material. The shunt was tested to assess the proximity effects of the return conductor and of ferromagnetic material. It was concluded that the particular Rogowski coils tested would not have measurement uncertainties of less than a few percent unless extreme care was taken in their calibration and subsequent use. The measurements for the shunt suggest somewhat less proximity effect than those for the coils. A digital oscilloscope was evaluated for possible use as a transient recorder. The effective number of bits, the differential linearity, and the response to a step function were determined.
[(301) 921-3121]

Van Brunt, R.J. and Anderson, W.E., **Bibliography of Data on Electrical Breakdown in Gases**, NBS Technical Note 1185 (April 1984).

Power Systems Metrology, cont'd.

This report consists of a bibliography of currently published data on electrical breakdown in gases. The bibliography contains a list of archival papers and books published since 1950, an index indicating the references that give particular types of data for each gas, an author index, and a list of relevant, regular technical conferences. The citations given in the bibliography contain experimental or theoretical data on breakdown which include:

(1) sparking potentials; (2) breakdown voltages; (3) critical fields, or field-to-gas density ratios; (4) corona inception voltages; (5) voltage-time characteristics; (6) relative and absolute dielectric strengths; and (7) breakdown probabilities.

Types of data considered include those which apply to uniform and nonuniform fields; ac, dc, and impulse voltages; and possible effects of particles, surfaces, interfaces, and corona. This bibliography is intended to serve as a guide in locating data on breakdown which are most relevant to particular applications. [(301) 921-3121]

Pulse Power Metrology

Released for Publication

McKnight, R.H. and Schoenwetter, H.K., **Capacitive Sensors for Voltage Measurements in Pulse Power Systems**, to be published in IEEE Proc. 16th Power Modulators Symposium [paper given at Symposium, Roslyn, VA, June 18-26, 1984].

Capacitive E-field sensors are frequently used in pulse power systems to measure voltage waveforms. Even though these sensors, often called "E-dot" sensors, are intrinsically simple in design and application, accepted techniques to evaluate their performance are not generally available. A laboratory test line has been constructed to facilitate detailed examination of the electrical characteristics of the sensors and to allow investigation of methods of calibrating such devices. Both discrete frequency and step-like signals can be placed on the line and the response of the sensor determined. Two different probe geometries have been studied with each showing the characteristic behavior of the capacitive sensor, including nanosecond rise time. The use of active electronic techniques has also been explored to extend the low frequency bandwidth of the measuring system. Sensors having a wide bandwidth are required for measurements of disconnect transients in gas-insulated power frequency equipment. [(301) 921-3121]

Magnetic Materials and Measurements

Recently Published

Goldfarb, R.B. and Minervini, J.V., **Calibration of AC Susceptometer for Cylindrical Specimens**, Review of Scientific Instruments, 55 (5), pp. 761-764 (May 1984).

The absolute magnetic susceptibility of cylindrical specimens is obtained with an ac susceptometer whose calibration is based on a calculation of mutual inductance. An axially magnetized cylinder is modeled as a solenoid of the same size. The mutual inductance between such a solenoid and a pickup coil of arbitrary dimensions is computed. The susceptibility is then a function of the mutual inductance, the cylinder length, the magnitude and frequency of the ac magnetizing field, and the voltage induced on the pickup coil. Demagnetization factor and eddy-current effects are considered, an example is given, and pickup coil compensation is discussed. [(303) 497-3650]

Misakian, M., Electrical Parameters in **60-Hz Biological** Exposure Systems and **Their Measurement: A Primer**, NBS Technical Note 1191 (April 1984).

This report presents material intended

Magnetic Materials & Meas., cont'd.

to facilitate the measurement of a number of electrical parameters that are of importance during bioeffects research involving 60-Hz electric and magnetic fields. The parameters that are considered are the electric field strength E, the magnetic induction or flux density B, field uniformity, harmonic content, phase relations between field components, and corona. Descriptions of the fields and methods for their laboratory generation are surveyed. The text is purposely elementary with references provided to aid the interested reader in obtaining a fuller understanding of many of the topics. It is shown that it is possible to characterize reasonably well the electric and magnetic fields used in animal exposure studies with relatively simple instrumentation.
[(301) 921-3121]

Superconductors

Released for Publication

Goodrich, L.F., Vecchia, D.F., Pittman, E.S., Ekin, J.W., and Clark, A.F., **Critical Current Measurements on a NbTi Superconducting Wire Standard Reference Material.**

This report reviews the selection and certification by NBS of a Standard Reference Material (SRM) for the measurement of superconducting critical current. Procedures for preparing and measuring five candidate conductors are described. Evaluation criteria are discussed by which one of the five conductors is selected for the critical current SRM. The designated superconducting wire, SRM 1457, has been subdivided and wound onto 500 spools for distribution. Certified critical current measurements were made on a sample of these spools. Material variability, or inhomogeneity, along the whole wire is included in a statistical model based on the dependence of critical current on temperature and electric field. Critical currents for SRM 1457 are certified at magnetic fields of 2, 4, 6, and 8 T for temperatures from 3.90 to 4.24 K and electric field criteria from 0.05 to 0.2 μV/cm. Statistical tolerance limits and estimated systematic errors are combined to give an overall uncertainty in the certified values. The total uncertainty is no greater than 2.57 percent of the reported critical current at any of the four magnetic fields. [(303) 497-3143]

Other Electrical Systems Topics

Recently Published

Anderson, W.E., **Microcomputer-Based Software for Management of Calibration Service**, NBSIR 84-2863 (April 1984).

The majority of the calibration customers' concerns are directed not to the technical details of the calibration service but to the timely delivery of that service. It is therefore proper that the calibration services be closely managed. For a Group or Division with a large calibration load, this can be a difficult task. The Applied Electrical Measurements Group of the Electrosystems Division has developed microcomputer-based software to provide considerable assistance to the calibration manager. With this database software, complete information on the status of all the calibration jobs is instantly available. [(301) 921-3121]

Palla, J.C. and Oravec, B.A., Compilers; Sorrells, J.R., Editor, **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division's Publications**, NBS List of Publications 94 (March 1984).

This bibliography lists the publications of the Electrosystems Division, Center for Electronics and Electrical Engineering, NBS, and of its predecessor sections, for the period January 1968 to March 1984. A brief description of the Division's technical program is given in the introduction.
[Contact: Sorrells, (301) 921-2727]

ELECTROMAGNETIC INTERFERENCE

Released for Publication

Adams, J.W. and Ondrejka, A.R., **Shielding Effectiveness (SE) Measurement Techniques,** to be published in Proc. EMI/RFI Technical Conference, The Society of Plastic Engineers, Inc. [paper given at Conference, Chicago, IL, June 18-20, 1984; based on paper presented at the 1984 IEEE EMC Symposium, San Antonio, TX, April 1984].

Five methods of measuring shielding effectiveness of the same lossy material were studied. Two of the methods were state-of-the-art involving time-domain techniques. Other methods include dual TEM cell, a variation of MIL-STD 285, and a coaxial holder. Comparative measurement data are shown, and insights are offered as to interpretation of results. Some methods give agreement; others do not. This is a preliminary analysis, not a definitive work. [(303) 497-3328]

Hill, D.A., **A Numerical Method for Near-Field Array Synthesis,** [extracted from NBS Technical Note 1072 (February 1984)].

A numerical method for near-field array synthesis is developed for arbitrary array geometries. The intended application is for generating a planar field in a test volume for electromagnetic susceptibility testing, but the method is valid for arbitrary field distributions. A uniqueness theorem is utilized to allow the field conditions to be enforced on the surface of the test volume rather than throughout the volume. The synthesis method is a least squares solution with a constraint on the source norm, and the constraint keeps the field small outside the test volume. Numerical results are shown for the case of synthesizing a plane wave in the near field of an array of line sources.
[(303) 497-3472]

Kanda, M., **An Electric and Magnetic Field Sensor for Simultaneous Electromagnetic Near-Field Measurements - Theory,** [previously published as NBS Technical Note 1062 (April 1983)].

This paper describes the theory of a single sensor to perform simultaneous electric and magnetic near-field measurements. The theory indicates that it is possible to obtain the magnetic-loop and electric-dipole currents using a loop terminated with identical loads at diametrically opposite points. The theory also indicates that it is possible to obtain an ideal load impedance for achieving equal electric and magnetic field responses of the loop. Preliminary experiments have been performed using plane waves to verify these results. [(303) 497-5320]

Ma, M.T., **Error Analysis of Radiation Characteristics of an Unknown Interference Source Based on Power Measurements,** to be published in the Proc. 1984 IEEE EMC [paper to be given at the 1984 IEEE International Electromagnetic Compatibility Symposium, Tokyo, Japan, October 16-18, 1984; based on NBS Technical Note 1064 (June 1983)].

Theoretical derivations, extracted from the power measurements made inside a transverse electromagnetic (TEM) cell, are given for analyzing the uncertainties in the source parameters and radiation characteristics of an unknown electrically small interference source. Numerical examples are also presented for cases in which measurement errors are assumed to be biased and unbiased and for the worst-case measurement situation. [(303) 497-3800]

Ma, M.T., Kanda, M., Crawford, M.L., and Larsen, E.B., **A Review of Some Electromagnetic Compatibility/Interference Measurement Methodologies.**

This paper presents a review summary of radiated emission and susceptibility measurement methodologies currently used for assessing the electromagnetic com-

Electromagnetic Interference, cont'd.

patibility/interference (EMC/EMI) characteristics of electronic devices and systems. In particular, measurement methods using open sites, transverse electromagnetic cells, reverberation chambers, and anechoic chambers are discussed, in light of their technical justifications and bases, their strengths and limitations, and interpretation of the measured results. [(303 497-3800]

Randa, J. and Kanda, M. **Multiple-Source, Multiple-Frequency Error of an Electric Field Meter.**

Electric field meters (EFMs) are typically calibrated using single-frequency, single-source standard fields. The response to multiple sources or nonsinusoidal time dependence may be different, however. Possible errors in a multiple-source, multiple-frequency environment are analyzed for an EFM consisting of an electrically short dipole antenna with a diode load and an RF filter transmission line. Also considered are errors in the assumption of equal electric and magnetic energy densities in a multiple plane-wave environment. Typical errors of field intensity measurements are about one to three dB but in some circumstances they can exceed 10 dB. [(303) 497-3150]

Wilson, P.F. and Ma, M.T., **Some Problems Associated with Interpreting Shielding Effectiveness Measurement Results,** to be published in Proc. EMI/RFI Technical Conference, The Society of Plastics Engineers, Inc. [paper given at Conference, Chicago, IL, June 18-20, 1984].

Shielding effectiveness is usually measured in terms of insertion loss, that is, the reduction in the fields coupled between a transmitter and receiver achieved by introducing the shield material or case, etc. Although the insertion loss concept is simply stated, problems arise when one attempts to interpret specific insertion loss measurements. Insertion loss depends not only on the shield introduced but also on antenna types used and their positioning, the waveform incident on the shield, and contact resistance. Variations in these factors can yield almost any level of insertion loss for the same shield sample. These concepts will be discussed to emphasize both the difficulty in making even relative insertion loss comparisons and the importance of controlling and understanding insertion loss parameters. [(303) 497-3842]

Wilson, P.F. and Ma, M.T., **Small Obstacle Loading in a TEM Cell,** to be published in Proc. 1984 IEEE EMC [paper to be given at the 1984 IEEE International Electromagnetic Compatibility Symposium, Tokyo, Japan, October 16-18, 1984].

A typical transverse electromagnetic (TEM) cell measurement procedure involves calibrating an empty cell and introducing a test object. The loading effect due to the test object presence is normally assumed to be negligible. This paper examines the effect of the test object and the validity of the "non-perturbing" assumption. The analysis utilizes the small aperture theory, as applied to the dual problem of small obstacle scattering. The result is an equivalent T-network representation of the test loading which allows the overall transmission line circuit to be studied. In addition, evaluating the scattered modes gives the field perturbation due to the test object. [(303) 497-3842]

Wyss, J.C., Anson, W., and Orr, D. **Building Penetration Project,** to be published as NBSIR 84-3009.

This report documents a computer program which calculates building attenuation of electromagnetic radiation over the frequency range 10 kHz - 10 GHz. Attenuation (in dB) is computed from building shape, dimensions, room layout, and the electrical properties of construction

Electromagnetic Interference, cont'd.

materials; no electromagnetic measurements are required. Details of the structure and use of the program are given.
[Contact: Anson, (303) 497-3989]

Recently Published

Crawford, M.L. and Koepke, G.H., **Operational Considerations of a Reverberation Chamber for EMC Immunity Measurements - Some Experimental Results**, Proc. 1984 IEEE National Symposium on Electromagnetic Compatibility, pp. 47-54 [paper given at Symposium, San Antonio, Texas, April 24-26, 1984].

This paper describes measurement procedures and results obtained from evaluation of a 2.74 m x 3.05 m x 4.57 m shielded chamber modified into a mode tuned reverberation chamber. A brief description of the measurement setup is given. The measurements described include an evaluation of the chamber's: (1) excitation and receiving antennas' voltage standing wave ratio and efficiency, (2) mode tuner effectiveness, (3) loss, and (4) electromagnetic test field statistical characteristics. In addition, the measurement results of two techniques to determine the field strength in the reverberation chamber are compared. Results shown cover the frequency range 200 MHz to 18 GHz.
[(303) 497-5497]

Driver, L.D. and Reeve, G.R., **Application of a Systematic Approach to an Investigation of HF Interference to a Shipboard Radar Set**, Proc. 1984 IEEE National Symposium on Electromagnetic Compatibility, pp. 221-228 [paper given at Symposium, San Antonio, Texas, April 24-26, 1984].

This paper describes an investigation of electromagnetic interference to a shipboard radar caused by a co-located HF, one kilowatt transmitter. The test procedures and analysis used to determine the points of EM field entry, the corrective measures taken, and the results achieved are described.
[(303) 497-3911]

Ondrejka, A.R. and Adams, J.W., **Shielding Effectiveness (SE) Measurement Techniques**, Proc. 1984 IEEE National Symposium on Electromagnetic Compatibility, pp. 249-256 [paper given at Symposium, San Antonio, Texas, April 24-26, 1984].

Five methods of measuring shielding effectiveness of a lossy material are compared. Comparative measurement data is shown, and insights are offered as to why the results do or do not agree. This is a preliminary analysis, not a definitive work.
[(303) 497-3309]

Wilson, P.F. and Ma, M.T., **Small Aperture Analysis of the Dual TEM Cell**, Proc. 1984 IEEE National Symposium on Electromagnetic Compatibility, pp. 365-369 [paper given at Symposium, San Antonio, Texas, April 24-26, 1984].

This paper describes an analysis of dual TEM cell coupling based on Bethe's small aperture theory. This approach allows one to model a variety of possible aperture shapes (circular, elliptical, square, etc.), including material loaded apertures of finite thickness. Measurements demonstrate that the theory accurately predicts coupling for an unloaded aperture.
[(303) 497-3842]

1984 CEEE CALENDAR

August 28-30 (Vail, CO)

Short Course on Optical Fiber Measurements. This course is addressed to scientists and engineers who are involved in fiber characterization. The course will emphasize concepts, techniques, and

CEEE Calendar, cont'd.

apparatus used in measuring the engineering parameters of telecommunication-grade fibers. A degree in electrical engineering or physics is assumed. The course will last three days with 18 hours of class time.
[Contact: Robert L. Gallawa (303) 497-3761]

September 10-11 (Santa Clara, CA)

VLSI Packaging Workshop. Sponsored by NBS and the IEEE Components, Hybrids, and Manufacturing Technology Society. The VLSI Chip Packaging Workshop has become the premier forum for technical professionals in the field of package development and analysis for VLSI integrated circuits. The Workshop addresses large chips, high-lead-count packages, conventional and pin-grid-array chip-carriers, TAB and wire bonding, and electrical and thermal performance of packages. All attendees are expected to be specialists working in the field, and to participate in the discussions. The Workshop is conducted as a single plenary session, with each of the four sessions containing a number of half-hour papers in addition to several shorter technical updates on current work. [Contact: G.G. Harman (301) 921-3621]

October 2-3 (Boulder, CO)

Symposium on Optical Fiber Measurements. This symposium, the third in the series of biennial meetings, is co-sponsored by the National Bureau of Standards, the Optical Society of America, and the Optical Waveguide Communications Committee of the Institute of Electrical and Electronics Engineers. Papers have been solicited "for any experimental or analytical aspect of the characterization of optical fibers and fiber optics systems, including attenuation, bandwidth/distortion, dispersion, index profile, cut-off wavelength, mode diameter/core geometry, fiber-device (e.g., joint, coupler, multiplexer) evaluation, physical measurements, link parameters (e.g., concatenation), polarization characteristics, system performance, field measurements, and standards."
[Contact: Douglas L. Franzen (303) 497-3346]

October 15-17 (Boulder, CO)

Symposium on Optical Materials for High Power Lasers. The Symposium is the principal forum for the exchange of information on the physics and technology of materials for high-power lasers. Topics to be discussed include new materials, bulk damage phenomena, surface and thin film damage, design considerations for high-power systems, and fundamental mechanisms of laser-induced damage. The series of conference proceedings resulting from these annual symposia has collectively become the principal repository of information on optics for all aspects of high-power/high-energy lasers, including, in addition to the subjects given above, environmental degradation, durability, fabrication, material growth and deposition processes, and testing.
[Contact: Aaron A. Sanders (303) 497-5341]

November 6-8 (Las Vegas, NV)

1984 Government Microcircuit Applications Conference (GOMAC). This Conference, for which NBS serves as one of a number of Government sponsors, includes sessions covering applications of silicon and gallium arsenide microelectronic circuits, circuit design and packaging considerations, reliability considerations, radiation hardness, signal processing applications, and other systems applications. With respect to circuits, specific sessions are concerned with memory technology, analog-to-digital and

CEEE Calendar, cont'd.

digital-to-analog data converters, gallium arsenide digital devices, and gallium arsenide analog monolithic integrated circuits. Conference attendance is restricted to U.S. citizens and immigrant aliens. [Contact: Jay Morreale (212) 620-3371]

NEW STANDARD REFERENCE MATERIALS

Two new Standard Reference Materials (SRMs) for calibrating equipment used to make spreading resistance measurements have been released by the Semiconductor Materials and Processes Division to the NBS Office of Standard Reference Materials for sale to the public. SRM 2526 applies to (111)-oriented p-type silicon surfaces and SRM 2527 to $\overline{(111)}$-oriented n-type silicon surfaces. Each SRM consists of a set of 16 specimens of silicon, approximately 6 x 12 mm in area and mounted on beveled metal blocks for convenient use in calibrating commercial spreading resistance equipment. These silicon chips have resistivities ranging from about 0.001 to 200 Ω•cm. The uncertainties in resistivity range typically from 2 to 5 percent for p-type specimens and from 4 to 10 percent for n-type. Two companion SRMs for $\overline{(100)}$ silicon surfaces are about to be released (2528, p-type and 2529, n-type).

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Center for Electronics and Electrical Engineering

10. SUPPLEMENTARY NOTES

All technical information included in this document has been approved for publication previously.

[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This is the seventh issue of a quarterly abstract journal covering the work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the Center for Electronics and Electrical Engineering Technical Progress Bulletin covers the second quarter of calendar year 1984. Abstracts are provided by technical area for both published papers and papers approved by NBS for publication.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

antennas; electrical engineering; electrical power; electromagnetic interference; electronics; instrumentation; laser; magnetics; microwave; optical fibers; semiconductors; superconductors.

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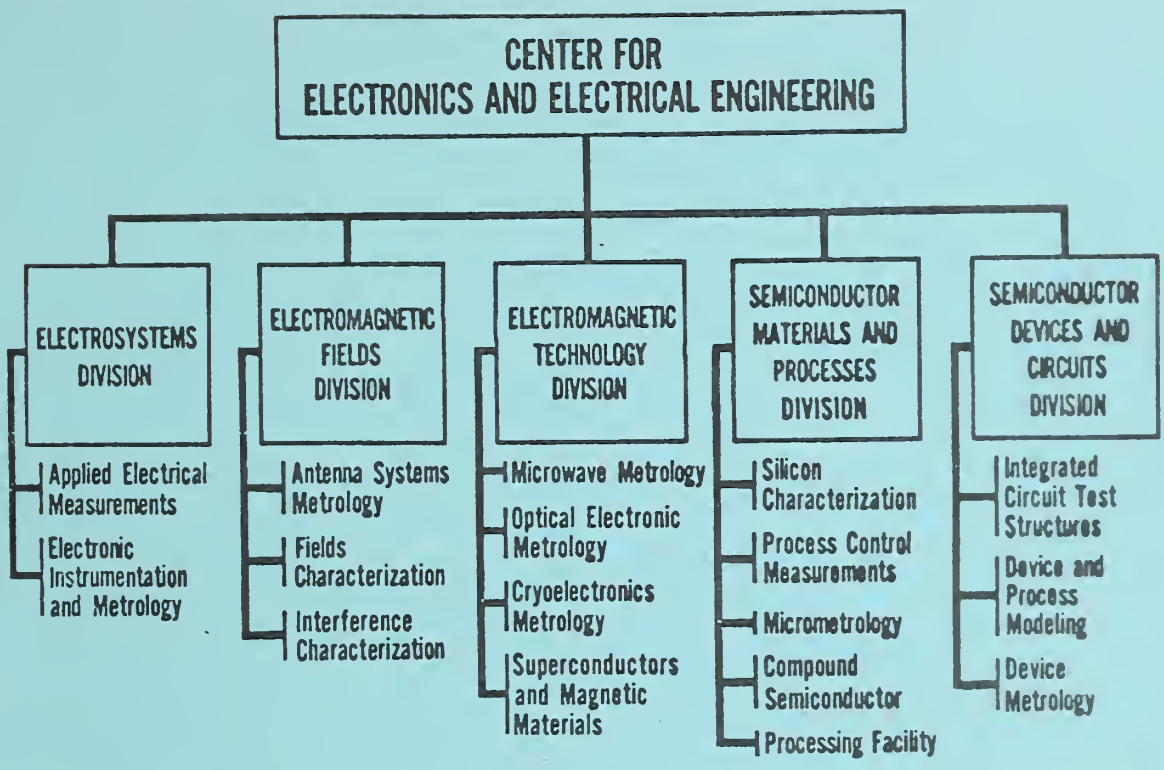

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